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RV *Investigator*

CTD Processing Report

Voyage #:	IN2018_V02
Voyage title:	SOTS: Southern Ocean Time Series automated moorings for climate and carbon cycle studies south west Tasmania; Subantarctic Biogeochemistry of Carbon and Iron.
Depart:	Hobart, 0800 Saturday 3 March 2018
Return:	Hobart, Tuesday, 20 March 2018
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Contents

1 Summary

These notes relate to the production of quality controlled, calibrated CTD data from RV Investigator voyage in2018_v02, from 03 Jan 2018 – 21 Mar 2018.

Data for 7 deployments were acquired using the Seabird SBE911 CTD unit 24, fitted with 36 twelve litre bottles on the rosette sampler. Samples were collected on casts 2-6. Sea-Bird-supplied calibration factors were used to compute the pressures and preliminary conductivity values. CSIRO - supplied calibrations were applied to the temperature data. The data were subjected to automated QC to remove spikes and out-of-range values.

The final conductivity calibration for each deployment was calculated using the sensors with the lowest residuals when compared with the values measured by the hydrochemistry team. The final calibration from chosen sensors all had a standard deviation (S.D) less than our target of 'better than 0.002 PSU'. The standard product of 1dbar binned averaged were produced using data from the primary conductivity and temperature sensors and the secondary oxygen sensor.

The dissolved oxygen data calibration generally showed a good agreement between the CTD and bottle data.

A Biospherical photosynthetically active radiation (PAR), Wetlabs transmissometer, Chelsea fluorometer and the Wetlabs ECO chlorophyll and Eco-scattering sensors were also installed on the auxiliary A/D channels of the CTD. An IMU and LADCP unit was also attached to the rosette for all casts.

Voyage Details

1.1 Voyage Title

SOTS: Southern Ocean Time Series automated moorings for climate and carbon cycle studies south west Tasmania; Subantarctic Biogeochemistry of Carbon and Iron.

1.2 Principal Investigators

The Chief Scientists on board was Tom Trull, CSIRO. Also on board was PI Phillip Boyd from UTAS.

1.3 Voyage Objectives

For details on the objectives of the voyage, refer to the Voyage Plan and/or summary which can be viewed on the CSIRO MNF web site.
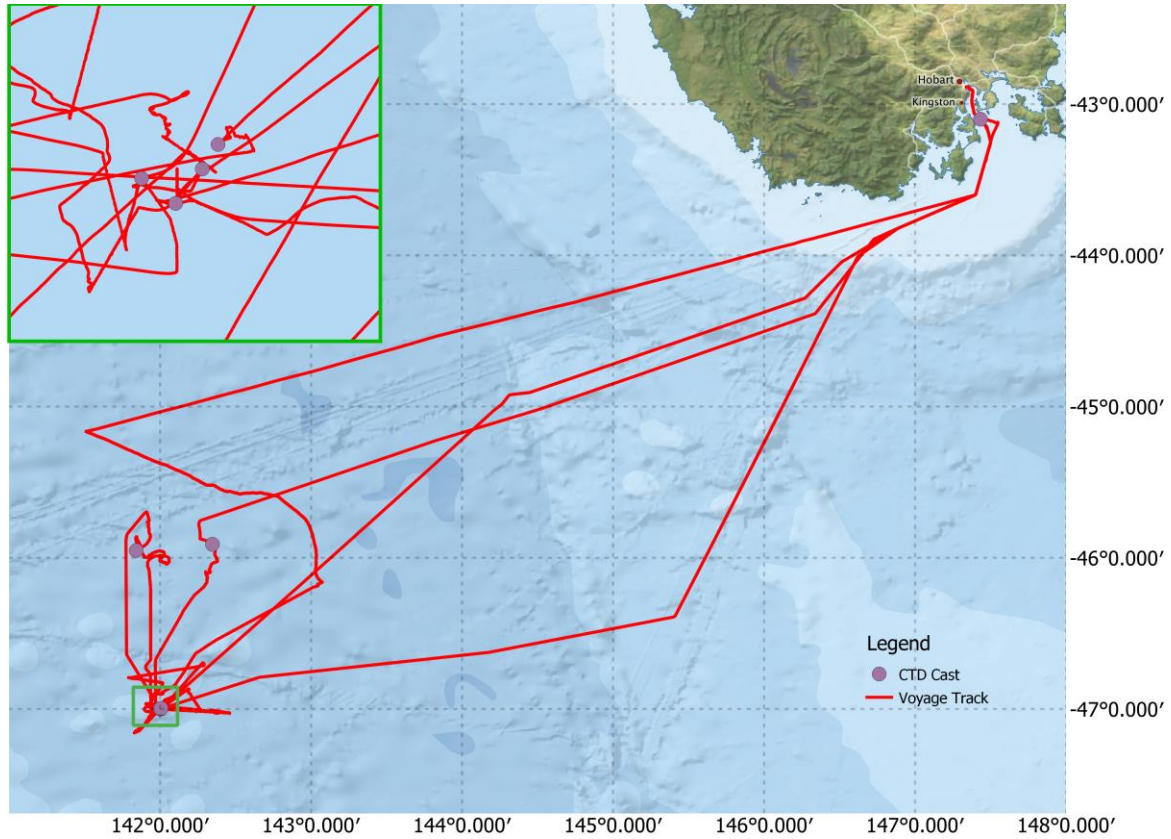
1.4   Area of operation

Figure 1. Area of Operation for in2018_v02 CTDs

2   Processing Notes

2.1   Background Information

The data for this voyage were acquired with CTD SBE9+ unit 20 with dual conductivity and temperature sensors. There were 7 deployments for this voyage as shown on Figure 1.

Rapp Hydema heave compensation was used on the CTD winch for all casts.

A Biospherical photosynthetically active radiation (PAR), Wetlabs transmissometer and the Wetlabs ECO chlorophyll and Eco-scattering sensors were also installed on the auxiliary A/D channels of the CTD. These sensors are described in Table 1 below.

Unit	Data Channel	SBE9 Connector	Model	Serial Number
CTD			SBE9+ V_2	#24 – 1332
Deck Unit			SBE11 V_2	0513
Primary Temperature	JB1		SBE3T	4522
Primary Conductivity	JB2		SBE4C	4685
Secondary Temperature	JB4		SBE3T	4722

Secondary Conductivity		JB5	SBE4C	4664
Primary Pump		JB3	SBE5	8344
Secondary Pump		JB3	SBE5	8345
Primary Oxygen casts 1-3	A0	JT2	SBE43	3154
Primary Oxygen casts 4-5	A0	JT2	SBE43	3198
Primary Oxygen casts 6 -7	A0	JT2	SBE43	3534
Secondary Oxygen	A1	JT2	SBE43	3155
Fluorometer Chelsea Aquatracker	A2	JT3	PA 500	11-8206-001
Altimeter	A3	JT3	PA 500	05301.228403
Transmissometer	A4	JT5	Wetlabs CSTAR 25cm	1421DRT
PAR	A5	JT5	QCP-2300-HP	70111
Wetlabs ECO – Chlorophyll (A6)	A6	JT6	FLBBNTU	4799
Wetlabs ECO – Scattering (A6)	A7	JT6	FLBBNTU	4799
MNF IMU	Serial	JT4	NA	NA

Table 1. CTD Sensor configuration for in2018_v02 CTDs

There were 7 CTD casts. The first was a test cast only to 10m, the last cast was a profile only, collecting water for the Calibration Facility at 100m. For the remaining casts water samples were collected using a Seabird SBE9+ 36-bottle rosette sampler with twelve litre bottles fitted to the frame.

There were steady readings from the secondary oxygen sensor, however until cast 5 noisy and divergent signals were recorded from two faulty primary oxygen sensors. The secondary oxygen channel readings improved when a third sensor was fitted for cast 6.

The raw CTD data was acquired using an SBE9/11+ and the SeaSave software version 7.26. A conductivity advance of 0.073 seconds was applied in the deck box to both the primary and secondary conductivity. The SeaBird hex files were converted to scientific units using SeaSave data processing. NetCDF files were created from the resultant CNV files with cnv_to_scan, an in-house python script.

The netCDF files were processed using CapPro v2.8. This Matlab software was used to apply automated QC and preliminary processing to the data. This included spike removal, identification of water entry and exit times and the determination of the pressure offsets. The automatically determined pressure offsets and in-water points were inspected and adjusted where necessary. The hydrology data were loaded and CapPro computed the matching CTD sample burst data.

The bottle sample data were used to compute final conductivity and dissolved oxygen calibrations. These were applied to the data and binned 1dB averaged data files were produced.

2.2 Pressure reference

The surface pressure offsets are plotted in Figure 2 below. The blue circles refer to initial out-of-water values and the red circles the final out-of-water values.
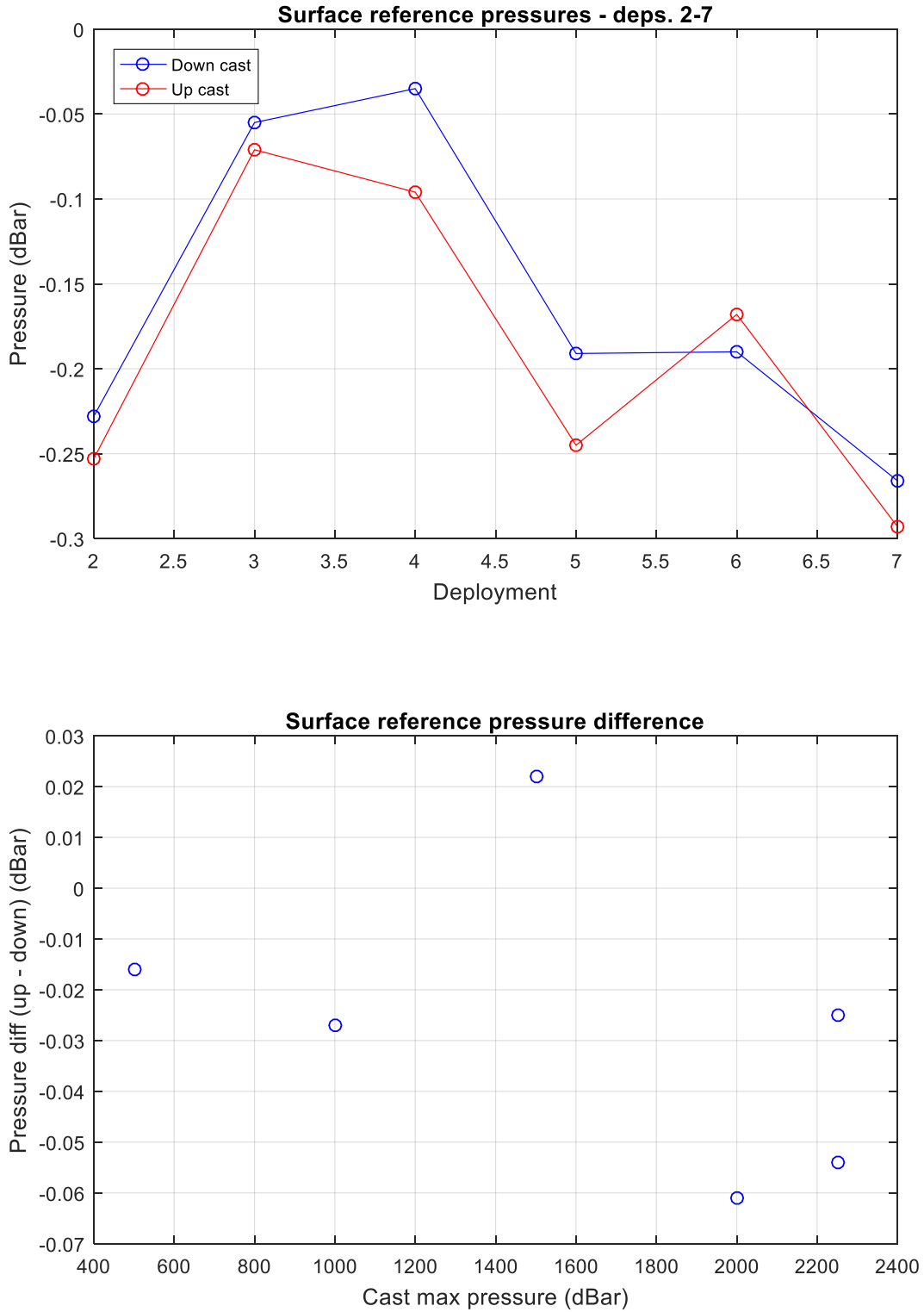

Figure 2. CTD pressure reference

The mean difference between the primary and secondary temperature sensors is plotted below. Most deployments should plot within ±1 m°C. Figure 3 indicates neither sensor has drifted significantly from its calibration.
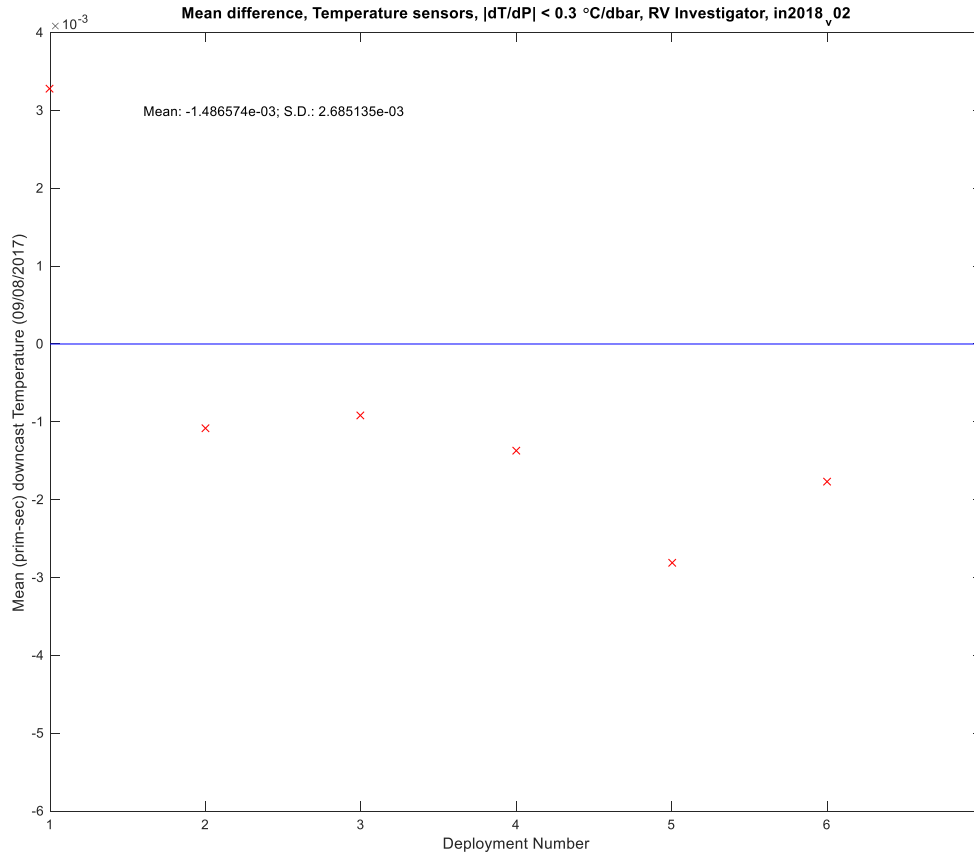

Figure 3. Temperature sensor difference

2.3   Conductivity Calibration

Discrepancies and possible sampling problems between bottle and CTD salinities for the primary conductivity sensor would show in Figure 4, the plot of calibrated (CTD - Bottle) salinity below. The primary conductivity calibration was based upon the sample data for 63 of the total of 85 samples, which meets our target of 75%. The secondary conductivity calibration was based upon sample data for 62 of the 85 samples which is slightly less than our target of 75%.

The outliers marked in the figures below with magenta dots are excluded from the calibration, the outliers marked with blue dots are used in the calibration but are weighted based on their distance from the mean. Any outliers marked with red crosses or dots are also excluded from the calibration.
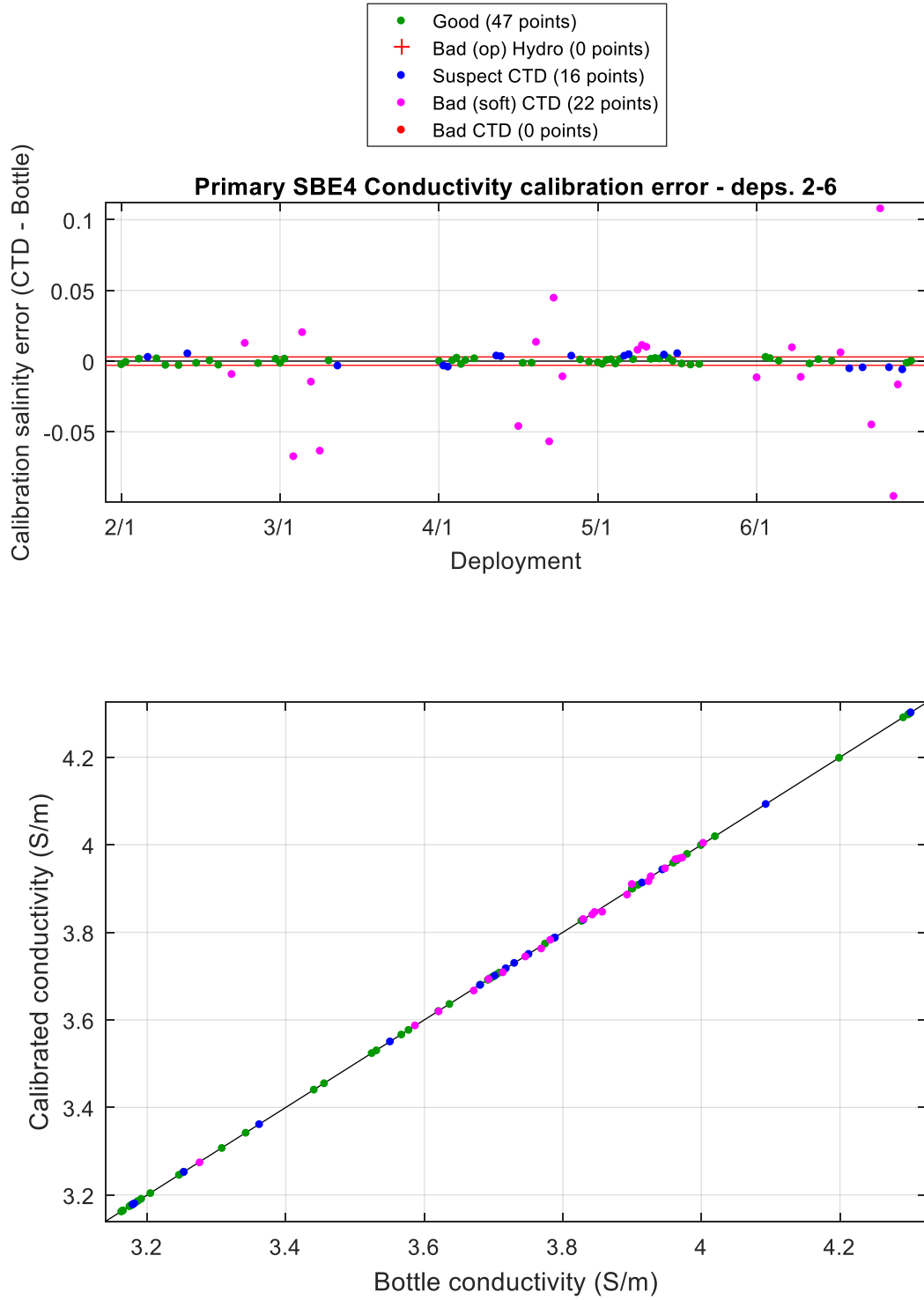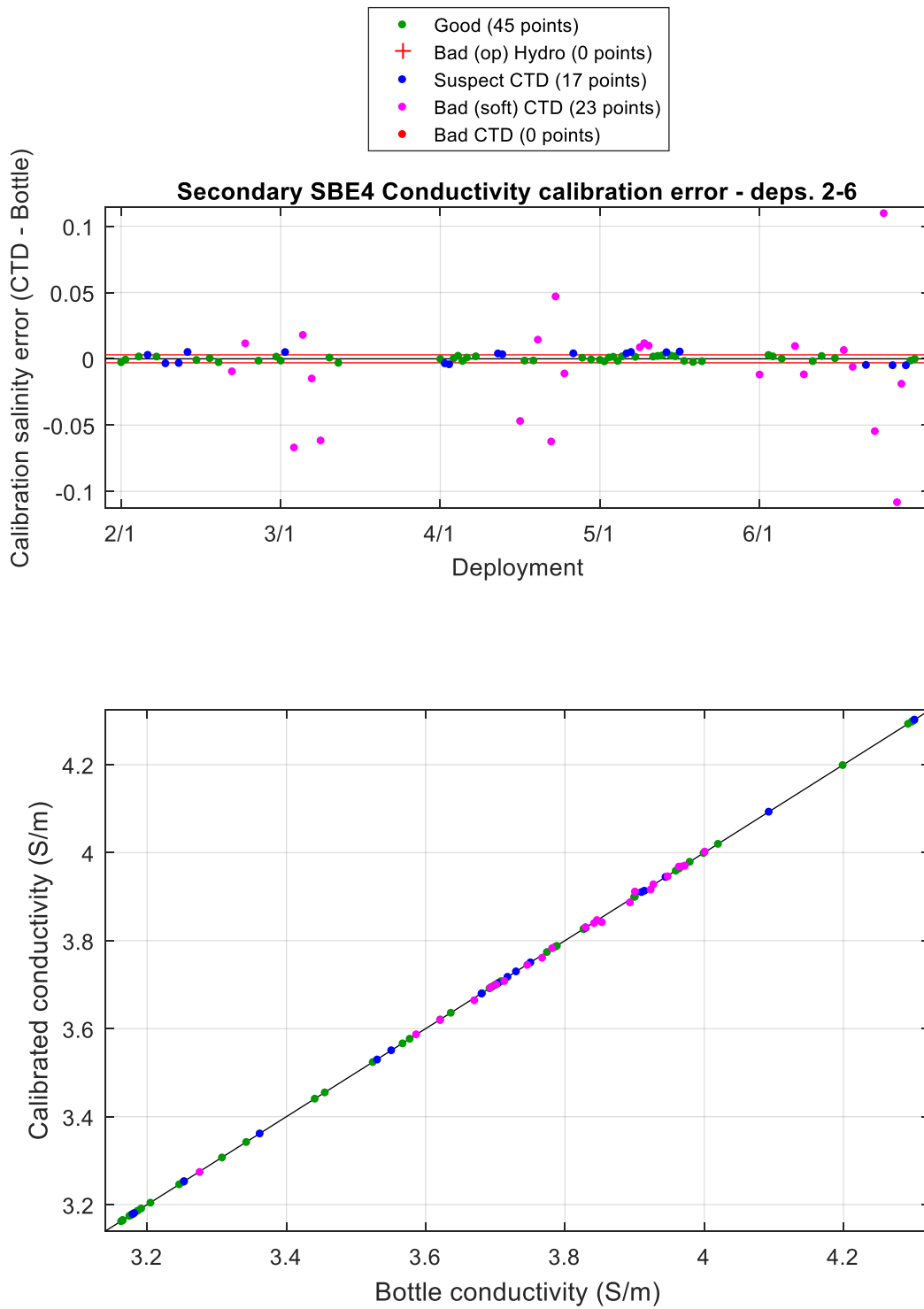
Figure 4. Primary conductivity calibrations

Figure 5. Secondary conductivity calibrations

The final result for the primary conductivity sensor was –

Cutoff 0.003

Scale Factor (a1)	0.99945	wrt. Manufacturer's calibration
Offset (a0)	0.0026693	ditto
Calibration S.D. (Sal)	0.0014685 PSU	

The calibration using the secondary conductivity sensor was –

Scale Factor (a1)	0.9994	wrt. Manufacturer's calibration
Offset (a0)	0.0029743	ditto
Calibration S.D. (Sal)	0.0014842 PSU	

Calibration standard deviation is the standard deviation of the difference between the calibrated values and the bottle values. This calibration is within the range we normally aim for, an S.D. of 0.002 psu or lower for 'typical' oceanographic voyages. The above calibration factors were applied to deployments 1 to 7.

Data from the primary conductivity and temperature sensors were used to produce the averaged salinities.

2.4   Dissolved Oxygen Sensor Calibration

Sea-Bird (2013) describes the SBE43 as "a polarographic membrane oxygen sensor having a single output signal of 0 to +5 volts, which is proportional to the temperature-compensated current flow occurring when oxygen is reacted inside the membrane. A Sea-Bird CTD that is equipped with an SBE43 oxygen sensor records this voltage for later conversion to oxygen concentration, using a modified version of the algorithm by Owens and Millard (1985)".

Calibration involves performing a linear regression, as per Sea-Bird (2012) to produce new estimates of the calibration coefficients Soc and Voffset. These new coefficients are used, along with the other, manufacturer-supplied coefficients, to derive oxygen concentrations from the sensor voltages.

2.5   Results

Deeper casts (>1000m) are known to be affected by pressure-induced hysteresis with this sensor. This is corrected automatically within CapPro using the method discussed by Sea-Bird (2014).

There is a small mismatch between downcast and upcast dissolved oxygen due to the response time of the sensor. No correction for the sensor lag effect has been applied.

The plots below are of CTD - bottle oxygen differences for both upcast and downcast data (red indicates 'bad' data).

As mentioned in Section 2.1 above, the secondary sensor was steady over all deployments. A single calibration group from the secondary sensor was used with the associated SBE43 up-cast data to compute the new Soc and Voffset coefficients. This is shown in Figure 7. See Figure 6 for the single deployment against which a primary sensor could be calibrated.
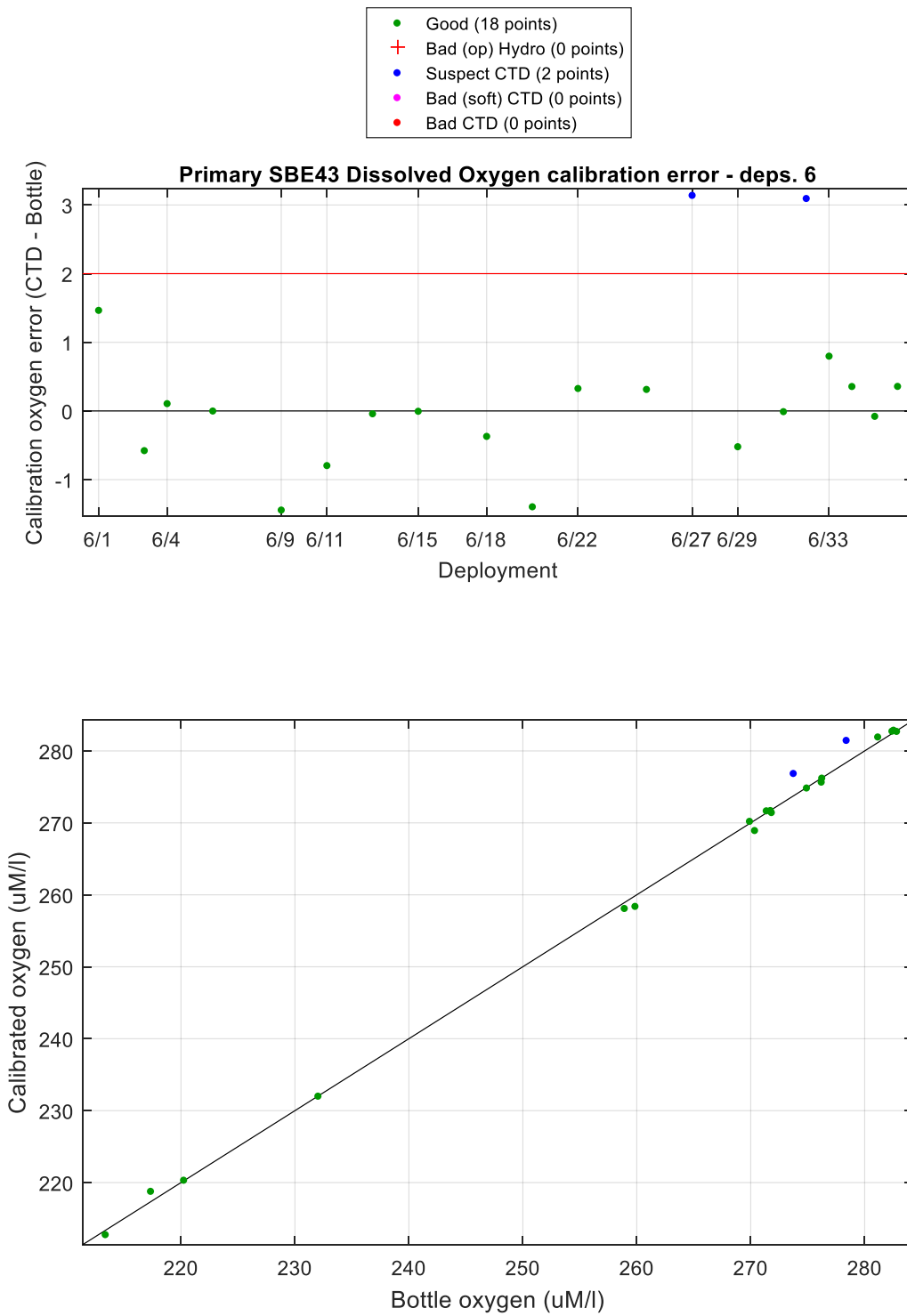
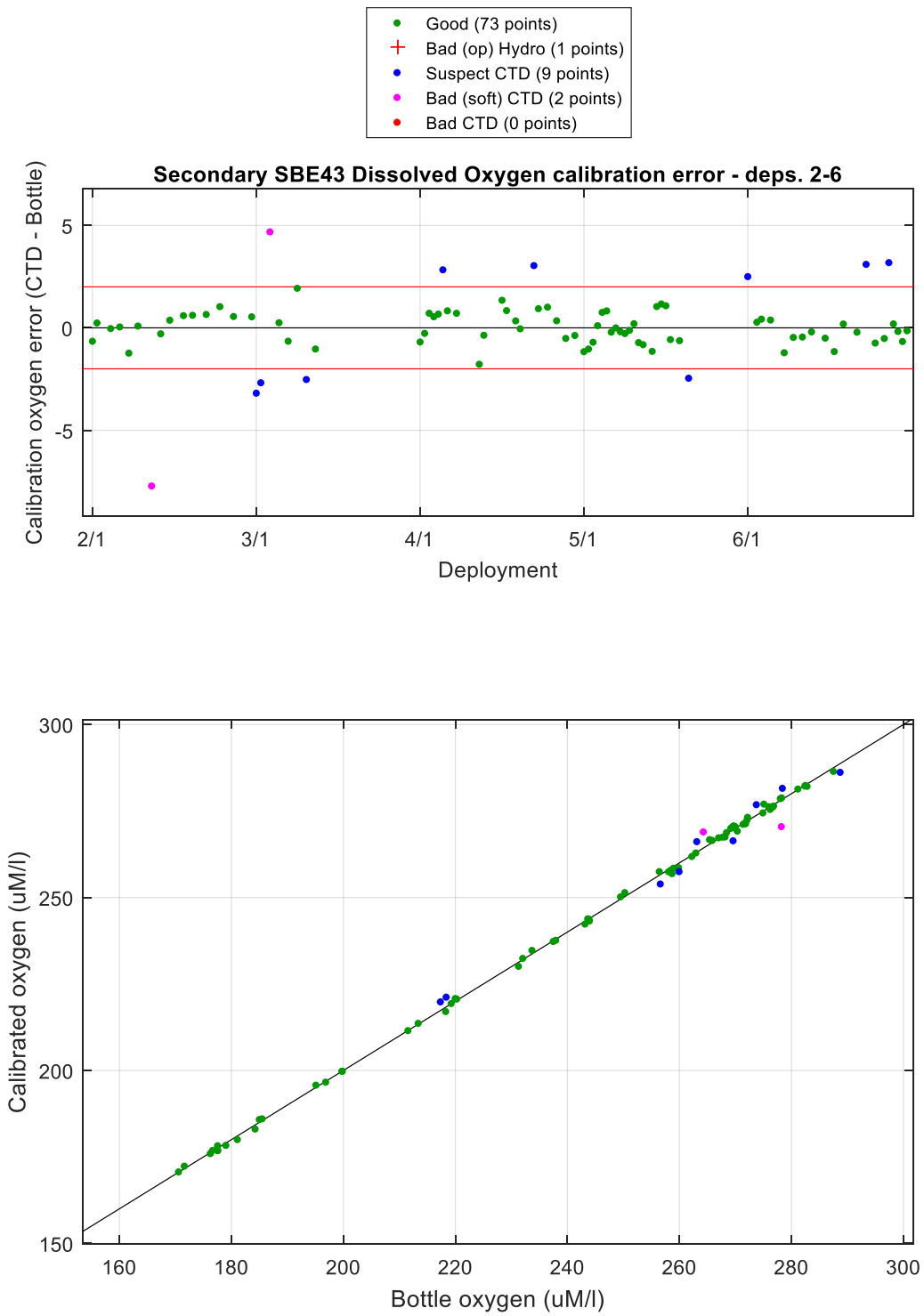*Figure 6. Dissolved Oxygen calibration, deployment 6 – primary sensor*

Figure 7. Dissolved Oxygen calibration, all deployments – secondary sensor

The old and new Soc and Voffset values for DO sensors are listed in Table 2 below. The Soc value is a linear slope scaling coefficient; Voffset is the fixed sensor voltage at zero oxygen. The calibration was applied for deployments 6 and 7 for the primary sensor. The final secondary sensor calibration was applied to all deployments. The averaged files were created using the result from the secondary sensor.

Calibration	Feb 2018 CSIRO	primary sensor (3534 cast 6)	Nov 2017 CSIRO	secondary (3155 casts 2-6)
Voffset	-5.3082e-01	-4.9568e-01	-5.134e-01	-4.8567e-01
Soc	5.3284e-01	4.98997e-01	5.3853e-01	5.2778e-01
Fit SD (uM)		0.9335		0.8067

Table 2. Dissolved Oxygen calibration

2.6   Other sensors

The C-Star transmissometer was used on all deployments. It was calibrated to give a nominal output of 0-100 fsd (full scale deflection).

A Chelsea fluorometer were both used for all deployments. It was calibrated to give an output of measured chlorophyll in µg/l using the Chelsea calibration.

The Biospherical PAR sensor was also used for all deployments. The output is a nominal 0-5 volts. This data channel has been included in the output files for all deployments. Clearly, time of day and environmental factors such as sea state and cloud cover impact on these readings. If most or all of the values for a deployment are near zero it indicates a night-time cast. In deployments where the PAR profiles have sub-surface maxima the CTD may have been shaded by the ship.

A Wetlabs ECO dual Chlorophyll and Scattering sensor was used on all deployments. The chlorophyll output is calibrated to give an output in mg/m^3 and the backscatter is calibrated to give an output in m^-1/sr using manufacturer supplied calibration factors.

2.7   Bad data detection

The limits for each sensor are configured in the CNV to Scan file conversion software and are written to the netCDF scan file. Typical limits used for the sensor range and maximum second difference are in Table 3 below. The rejection rate is recorded in the CapPro processing log file.

Sensor	Range min	Range max	Max Second Diff
temperature	-2	40	0.05
conductivity	-0.01	7	0.01
oxygen	-0.1	500	0.5
Transmissometer	0	100	0.5
Biospherical PAR	-5	5000	0.5
Wetlabs Flouorometer	-5	5000	0.5

Chelsea Flurometer	-5	100	0.5
Wetlabs OBS	-5	5000	0.5

Table 3. Sensor limits for bad data detection

2.8   Averaging

The calibrated data were 'filtered' to remove pressure reversals and binned into the standard product of 1dbar averaged netCDF files. The binned values were calculated by applying a linear, least-squares fit as a function of pressure to the sensor data for each bin, using this to interpolate the value for the bin mid-point. This method is used to avoid possible biases which would result from averaging with respect to time.

Each binned parameter is assigned a QC flag. Our quality control flagging scheme is described in Pender (2000).

The QC Flag for each bin is estimated from the values for the bin components. The QC Flag for derived quantities, such as Salinity and Dissolved Oxygen are taken to be the worst of the estimates for the parameters from which they are derived.

3   References

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